MSHA A&CC
MSD-DPSB
Diesel Test Laboratory

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[NOTE - This document has been modified by ARB: filter manufacturer specific information has been removed. For NO2 Working Group purposes only.]

STATUS UPDATE:

Tests of various catalyzed Diesel Particulate Matter (DPM) traps to determine DPM filtering efficiency and gaseous emissions.

Date: 6/3/02

Introduction:

MSHA Approval and Certification Center Diesel Laboratory has recently conducted a series of tests on several catalyzed DPM filters/traps which are capable of being used on underground diesel equipment. These tests were run to evaluate the efficiencies of the various traps and to determine their effect on gaseous emissions of the engine/trap combination. Since gaseous emissions of the diesel engine are regulated and ventilation requirements are set for the engine based on 30 CFR, Part 7 tests, the tests were conducted per Part 7 requirements, unless otherwise specified in this update.

Description:

The engine used for all tests was a Deutz F6L912W engine. This is a standard engine used in testing at the diesel lab, and is approved for mine use at an 80hp (@2300rpm) rating. It is not a "new" condition engine, but is probably in typical operating condition for an engine in a mine. The tests were run using the A&CC Diesel Laboratory 400hp dynamometer. Gaseous emissions were measured using a Horiba measurement bench to measure CO, CO_2, NOx and NO (NO_2 is calculated as the difference between NO and NOx measurements). DPM sampling was done using a Sierra BG-2 Micro-Dilution Test Stand.

The test cycle run for the tests was the ISO-8178 cycle used in Part 7 engine approval tests. This test cycle measures the steady state performance and emissions at 8 points over the operating range of the engine. The ISO-8178 test cycle for the Deutz F6L912W engine is shown in Table 1. The engine was baselined without a trap using the same test cycle and this baseline was used for comparison to the after trap data.

Table 1
ISO-8178 Test Cycle for Deutz F6L912W

Test Mode	Throttle	Torque (lb-ft) (%)	Torque (lb-ft) Value	Engine RPM Setpoint	Engine RPM Value	Power HP approx.	Inlet Vacuum setting[1] ("H2O)
1	Full	100	~200	Rated	2300	80	10
2	Partial	75	~143	Rated	2300	60	10
3	Partial	50	~95	Rated	2300	40	10
4	Partial	10	~19	Rated	2300	8	10
5	Full	100	~205	Peak Torque	1550	60	10
6	Partial	75	~158	Peak Torque	1550	45	10
7	Partial	50	~105	Peak Torque	1550	30	10
8	Idle	0	~3	Idle	660	0	10

[1] This is the engine manufacturers limiting intake vacuum for an engine with a clean intake air cleaner.

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The traps used in the testing are shown in Table 2. All the traps supplied by the original manufacturers were sized for the F6L912W engine. Filters B and G were supplied by third parties, not the original manufacturers. Filter B was however sized for the F6L912W engine. Filter G was not specifically sized to the F6L912W engine and Mfr G did not believe the trap appropriate for the F6L912W. A G trap sized to the F6L912W will be supplied by the manufacturer for testing at a later date.

Table 2
Traps Supplied for Testing

Manufacturer	Type
A	Base Metal Catalyst
B	Platinum Catalyst
C	Platinum Catalyst
D	Platinum Catalyst
E	Platinum Catalyst
F	Platinum Catalyst
G	Platinum Catalyst

Results:

The following discussion will be confined to the DPM efficiency results and the trap effects on the production of NO2. The effects on other regulated gaseous emissions will be discussed in a final report.

DPM Efficiency:

The efficiencies of the various DPM traps may be seen in Table 3 and Figure 1. Filter efficiency is defined as the % change in DPM emissions after the trap, relative to the engine baseline DPM emissions. The percent efficiencies are shown for each test mode in the ISO-8178 cycle. Most of the filters showed fairly consistent efficiency results and high removal rates of DPM. It is noted that some filters had lower efficiencies at test mode 1 (rated speed, full load), where exhaust flow is highest.

The bottom row in Table 3 shows the efficiency of the filter using the weighted average calculations for ISO-8178 test (per Part 7), comparing the weighted average DPM emission of the engine-only and the after-trap weighted average DPM. Most of the filters fall within a few percent of the manufacturers advertised efficiencies (with one excpetion), and is well within expected experimental variation.

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Table 3
DPM Efficiency Results for Trap Tests

Test Mode	A*	B	C	D	E	F	G
1	88.41	78.30	40.41	65.63	65.34	58.23	57.28
2	86.87	86.96	74.71	83.95	79.47	73.46	88.02
3	78.82	91.60	90.80	93.20	90.20	89.21	91.64
4	84.80	92.17	90.79	91.11	93.42	86.37	94.29
5	95.17	89.36	76.91	85.22	92.43	88.14	93.72
6	93.78	90.87	86.54	91.97	87.64	87.53	92.28
7	91.15	96.44	93.59	95.21	93.08	92.74	94.09
8	79.34	-28.54	75.42	82.06	71.71	79.17	78.25
Weighted Average	**88.49**	**87.01**	**74.96**	**84.24**	**84.37**	**80.15**	**85.16**

*- base metal

NO2 Emissions:

The NO2 (after filter) emission results are shown in Table 4 and Figure 2. The traps generally showed a dramatic increase in NO2 emissions over the engine-only NO2 emissions, except at light engine loads, where it tended to reduce NO2 emissions. The notable exception to the trend was the base-metal catalyst trap from ECS, which generally reduced NO2 emissions.

Table 4
NO2 Emissions (gr/hr) of Engine and Catalyzed Traps

Test Mode	1	2	3	4	5	6	7	8
Engine-Out (gr/hr)	18.0	36.4	30.7	25.0	11.5	17.7	23.4	10.6
A* (gr/hr)	7.6	20.8	11.7	17.8	13.6	25.9	8.1	5.5
% increase	**-57.7**	**-43.0**	**-62.1**	**-28.8**	**18.0**	**45.7**	**-65.2**	**-47.7**
B (gr/hr)	61.4	67.7	26.3	10.1	47.8	80.6	39.6	4.1
% increase	**241.1**	**85.7**	**-14.4**	**-59.5**	**315.9**	**354.3**	**69.5**	**-61.3**
C (gr/hr)	85.6	115.2	55.1	8.3	76.4	116.2	40.2	6.2
% increase	**375.9**	**216.3**	**79.2**	**-66.9**	**565.0**	**554.6**	**71.9**	**-41.7**
D (gr/hr)	59.3	98.2	48.1	3.0	60.6	90.6	32.2	5.2
% increase	**229.7**	**169.5**	**56.5**	**-88.2**	**427.3**	**410.7**	**37.8**	**-50.9**
E (gr/hr)	95.2	127.7	70.9	5.0	86.3	119.2	61.3	15.0
% increase	**429.1**	**250.7**	**130.6**	**-79.9**	**650.4**	**571.6**	**162.1**	**41.9**
F (gr/hr)	88.9	123.0	36.2	6.3	42.3	61.6	35.5	3.9
% increase	**394.3**	**237.7**	**17.7**	**-74.9**	**267.8**	**247.0**	**51.8**	**-62.9**
G (gr/hr)	76.9	122.1	66.9	7.7	79.4	105.4	62.1	8.0
% increase	**327.4**	**235.2**	**117.6**	**-69.3**	**590.7**	**493.7**	**165.7**	**-24.7**

Vent Rate Calculations for NO2:

Part 7 engine tests require the calculation of ventilation rates for CO, CO2, NO and NO2 for each test mode in the ISO-8178 test to determine how much fresh air is required to reduce the engine emissions to below the Threshold Limit Values (TLVs) specified in Part 7. The mode and gas producing the highest ventilation requirement (rounded up to the nearest 500CFM) is then specified as the nameplate ventilation rate for the engine, which should keep that gas, and all the others from approaching the TLVs in the mine environment. For the Deutz F6L912W, this nameplate value is 4500CFM, which is based on NO emissions at mode 1. NO2 ventilation requirement for the F6L912W are always far below 4500CFM, which never allow the NO2 TLV (5ppm) to be approached.

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For each of the traps tested, ventilation rates were calculated for the emissions of NO2 from the traps. These results are shown in Table 5 and Figure 3. For any ventilation value in the table that is over 4500CFM, the nameplate ventilation rate could not be expected to keep NO2 values in the mine environment below the TLV of 5ppm. For any ventilation value higher than the corresponding engine-only value at that mode, even if below 4500CFM nameplate, a degradation in the mine ambient NO2 levels is possible, relative to an engine without a DPM trap.

Table 5
NO2 Ventilation Requirements for Trap Emissions

Test Mode	1	2	3	4	5	6	7	8
Engine Only (no trap)	**1088**	**2203**	**1860**	**1513**	**695**	**1074**	**1414**	**640**
A	460	1256	706	1078	820	1565	493	335
B	3712	4092	1593	612	2893	4878	2397	248
C	5178	6969	3332	501	4624	7029	2431	373
D	3588	5939	2910	179	3667	5483	1948	314
E	5757	7727	4288	305	5218	7211	3707	907
F	5379	7441	2189	380	2558	3726	2147	237
G	4651	7387	4048	465	4803	6374	3758	481
	(CFM)	(CFM)	(CFM)	(CFM)	(CFM)	(CFM)	(CFM)	(CFM)

*-base metal catalyst

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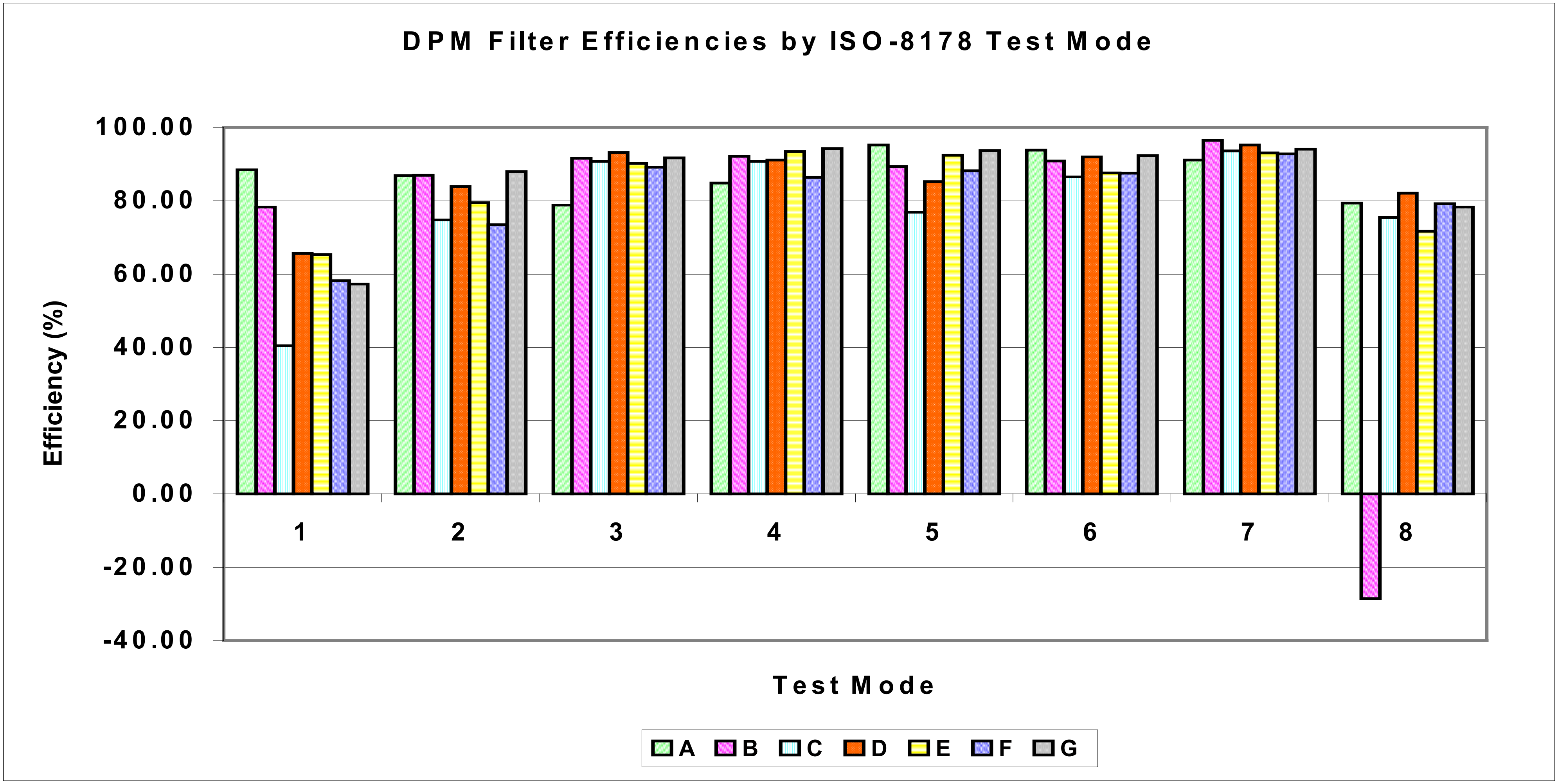

Figure 1: **DPM Efficiency Results for Trap Tests**

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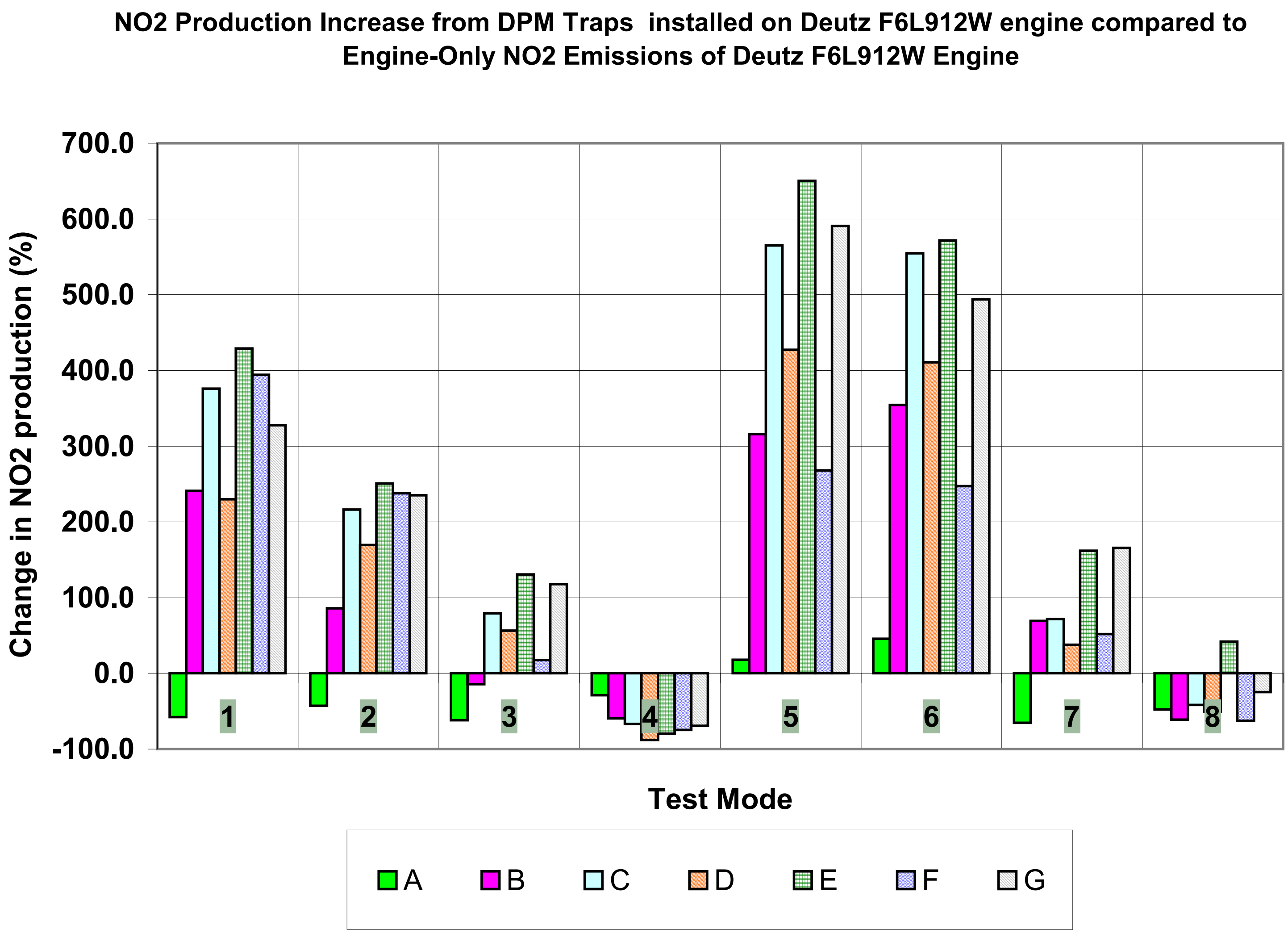

Figure 2: NO2 Emissions (gr/hr) of Engine and Catalyzed Traps

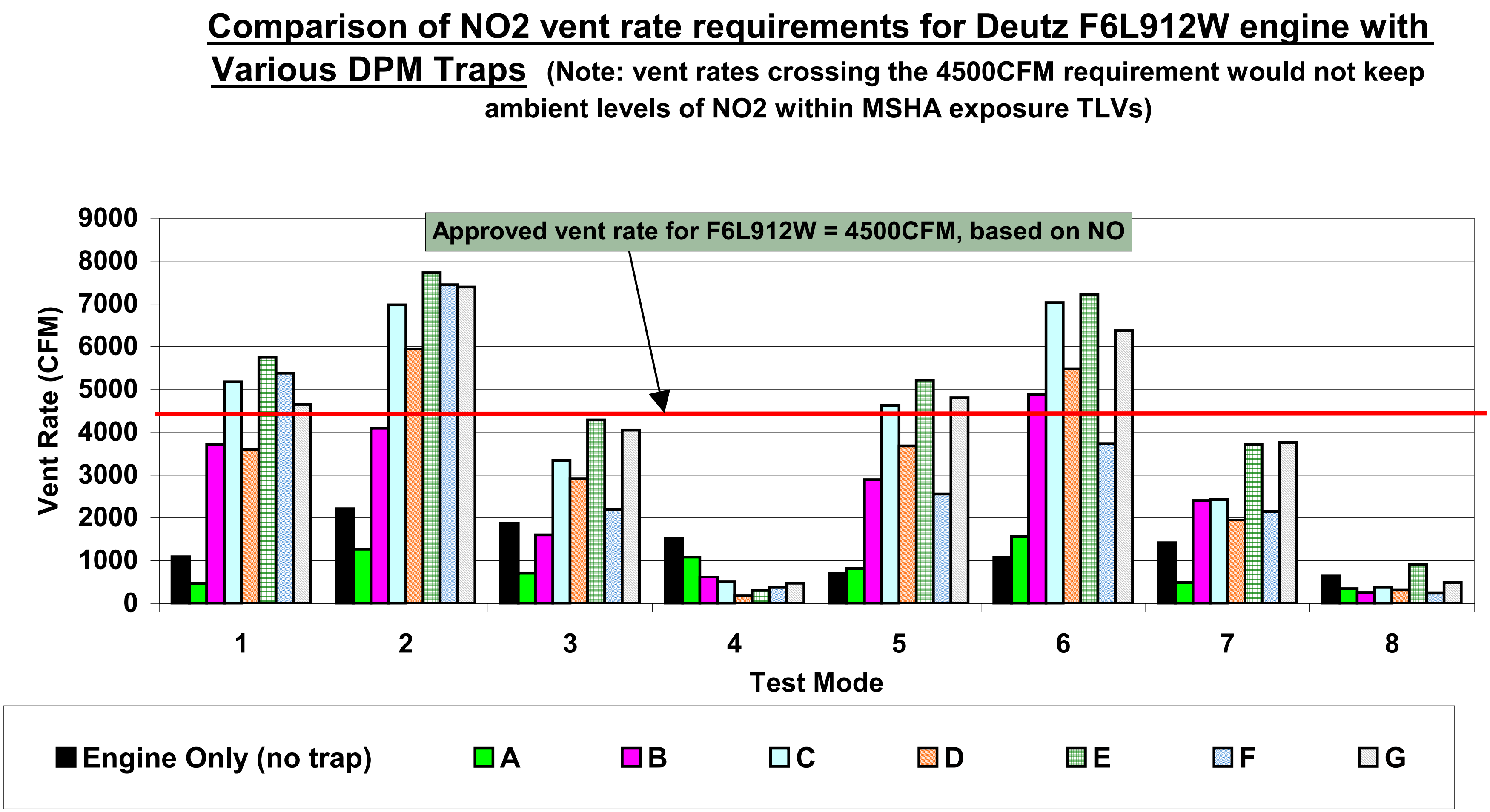

Figure 3: NO2 Ventilation Requirements for Trap Emissions